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Space systems — Unmanned spacecraft design, performance and quality assessment — General test methods for system, subsystem and unit levels

Systèmes spatiaux — Évaluation de la conception, de la performance et de la qualité des véhicules spatiaux non habité — Méthodes d'essai générales aux niveaux système, sous-système et équipement

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Pour accélérer la distribution, le présent document est distribué tel qu'il est parvenu du secrétariat du comité. Le travail de rédaction et de composition de texte sera effectué au Secrétariat central de l'ISO au stade de publication.

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

ISO 15864 was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Introduction

Throughout this International Standard, the minimum essential criteria are identified by the use of the key word “shall.” Recommended criteria are identified by the use of the key word “should,” and while not mandatory are considered to be of primary importance in providing serviceable, economical and practical designs. Deviations from the recommended criteria should occur only after careful consideration, extensive testing, and thorough service evaluation have shown alternative methods to be satisfactory.

Space systems — Unmanned spacecraft design, performance and quality assessment — General test methods for system, subsystem and unit levels

1 Scope

1.1 Purpose

This draft International Standard provides the baseline standard on the subject of testing at the system, subsystem, and unit level for applicable unmanned spacecraft programs. It also provides the requirements for documentation associated with testing activities.

1.2 Application

The acceptance criteria, specifications or procedures, and other detail test requirements applicable to a particular program are defined in the applicable technical specifications and statement of work. When requirements have to be verified by measuring product performance and function under various simulated environments, the method is referred to as "Test." The requirements of this International Standard may be tailored for each specific space program application.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 14302:2002, *Space systems — Electromagnetic compatibility requirements*

ISO 14303:2002, *Space systems — Spacecraft to launch vehicle interface*

ISO 14623[1)], *Space systems — Requirements for safe design and operation of pressure vessels and pressurized structure*

ISO 15863[1)], Space systems — Spacecraft to launch vehicle interface control document

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

1) To be published

3.1.1
development model
representative of spacecraft, subsystem, or unit dedicated to increase confidence in design and subjected to development tests

3.1.2
flight model
spacecraft, subsystem, or unit model dedicated to be launched and operated in orbit and subjected to acceptance testing

3.1.3
limit load
maximum predicted load or combination of loads that a structure may experience during its service life in association with the applicable operating environments

3.1.4
maximum and minimum predicted temperatures
highest and lowest temperatures that can be expected to occur during the entire life cycle of the subsystem/unit in all operational modes plus an uncertainty factor

3.1.5
operational modes
modes for spacecraft, subsystems, and units that include all combinations of operational configurations that can occur during service life

EXAMPLE Power on or power off, main or redundant system selected.

3.1.6
proto-flight model
model that is subjected to the qualification levels and acceptance duration

3.1.7
qualification model
spacecraft, subsystem, or unit dedicated to qualify the design of flight model and subjected to qualification testing

3.1.8
quasi-static load
load with magnitude and direction that are independent of time; or load that varies slowly and in which dynamic response of the structure is insignificant

NOTE This load can be induced by steady wind, aerodynamic forces, thrust (constant or wind slow variations), maneuvers and spin stabilization.

3.1.9
spacecraft
spacecraft of an integrated set of subsystems and units capable of supporting an operational role in space

3.1.10
subsystem
assembly of functionally related units

3.1.11
test article
spacecraft, subsystem, or unit on which a test is conducted

3.1.12
test facility
location, (including equipment, fixture, and instrumentation) capable of performing a test

3.1.13
ultimate load
load to which a structure is designed; obtained by multiplying the limit load by the safety factor

3.1.14
unit
lowest level of hardware assembly for which acceptance and qualification tests are required

3.2 Abbreviated terms

AT	acceptance test
BBM	breadboard model
CG	center of gravity
EED	electroexplosive devices
EMC	electromagnetic compatibility
EMI	electromagnetic interference
LBB	leak-before-burst
MEOP	maximum expected operating pressure
MMA	moving mechanical assembly
PFT	proto-flight test
QT	qualification test
RF	radio frequency

4 General requirements

4.1 Testing philosophy

In principle, testing is one verification method that ensures that the spacecraft meets all design, performance, and product assurance requirements. This International Standard contains provisions for qualification and acceptance testing, or proto-flight testing (PFT). It assumes that hardware development is complete.

Performance requirements contained in the contract documentation are compared to performance achieved during testing and provide the basis for judging the capability of the spacecraft to operate as intended. Besides verifying performance, test programs provide the following items:

a) training for personnel in operation of the spacecraft;

b) incorporation of corrective actions taken for nonconformances;

c) validation of data processing;

d) opportunity to perform calibrations under simulated space conditions;

e) verification of ground hardware compatibility with the spacecraft for operations.

Factors that contribute to the provisions of test specifications include experience with similar spacecraft, subsystem, and unit; cost considerations; and reliability requirements. This International Standard contains range conditions to which the items under test shall be operated and test conditions that shall be used to demonstrate capability.

4.2 Tailoring of requirements

The test requirements may be tailored to fulfill the objectives of individual tests. Tailoring parameters shall be determined by negotiations among the customer, spacecraft manufacturer, and launch service provider.

4.3 Development tests

Development tests support design feasibility and assist in evolution of design. Development tests are necessary to validate new design concepts and the application of proven concepts and techniques to a new configuration. Development tests are used to confirm structural and performance margins, manufacturability, test simplification, maintainability, reliability, lifetime prediction, and compatibility with safety. Therefore, requirements for development testing depend on the maturity of the design used and the operational requirements of the specific project. By its nature, development testing cannot be reduced to a standardized set of procedures.

Where practicable, development tests shall be conducted over a range of operating conditions that exceed design limits to identify marginal design features. Development tests may be conducted on mock-ups, breadboards, models, or integration models.

4.4 Qualification tests

Qualification tests demonstrate that items meet design requirements and include proper margin. The qualification test level shall exceed the maximum predicted levels by a factor of safety or qualification margin; unless otherwise specified, the qualification test duration shall be longer than maximum environment duration with appropriate qualification margin. In addition, qualification tests shall validate methods, procedures, facility conditions, and ground support test equipment that will be reused for acceptance.

4.5 Acceptance tests

Acceptance tests shall demonstrate that the item is free of workmanship defects and integration errors and that its function and performance to the extent practicable can meet stipulated mission requirements. Acceptance tests detect latent material or workmanship defects introduced during the manufacturing and assembly process by measuring function and performance parameters. Such parameters shall be measured through sequential tests to identify function and performance degradation that is likely to damage mission purposes and to establish a baseline to ensure that no degradation is found in the data history.

4.6 Proto-flight tests

It shall be recognized that the proto-flight approach presents a higher risk than the approach in which design margins are demonstrated by the testing of a dedicated nonflight qualification item. Moreover, programmatic realities of limited production, tight schedules, and budgetary limits do not always allow the use of dedicated nonflight qualification items. In response, several strategies have evolved to minimize the risk created by this situation. The higher risk of the proto-flight approach is an example. In principle, the proto-flight approach may be applied at each level of decomposition of the space system.

Proto-flight tests shall qualify the design and manufacturing methods of hardware for the purpose of acceptance for flight operations. Qualification of design and manufacturing methods is accomplished by imposing environmental levels more severe than environments expected during ground and orbital operations. Hardware fatigue is prevented by limiting exposure so not to expend a significant portion of the useful life of the hardware. These tests also detect latent material and manufacturing defects and provide experience with each test item's performance under conditions similar to the mission environment.

4.7 Prelaunch validation tests

Prelaunch validation tests shall be conducted at the launch site, if it is necessary for spacecraft. These tests demonstrate that transportation to and handling at the launch site cause no spacecraft parameter changes and verify that spacecraft and launch vehicle interface and compatibility testing with the Tracking and Control System stay within the stipulated limits as part of launch site operations. The tests shall exercise spacecraft within practical limits in order to ensure that all mission requirements can be satisfied.

4.8 Retest

In principle, there are four situations that may require retest.

4.8.1 Retest due to design modification after completion of qualification

Whenever hardware design is modified, the hardware involved shall be retested as necessary, and all documentation pertinent to the design modification shall be revised. Depending on the type and extent of the implemented modification, the issue of whether to partially or completely repeat the qualification test sequence shall be evaluated. The acceptance test sequence shall be either partially or completely repeated to demonstrate that no new problems have been introduced.

4.8.2 Retest due to nonconformance

If nonconformance occurs during testing activities, necessary action shall be taken in accordance with the test procedure, and the causes of nonconformance shall be identified. If nonconformance is caused by the test set-up, test software, or failures in test equipment, the test being conducted at the time of the failure may be continued after repair is completed, as long as the nonconformance did not overstress the test items. If nonconformance caused in the test items is disposed, initial failure analysis and appropriate corrective action shall be completed before retesting. If a failure occurs during the environmental test, the test may be continued as long as the nonconformance does not affect continuity of the test.

The details of retesting shall be determined in consideration of the nature of each failure. If the units must be substantially redesigned, all previous qualification tests shall be repeated. After the redesign of the unit is qualified, all acceptance test programs shall be repeated.

4.8.3 Retest after refurbishment

Former qualification hardware is often refurbished to be used as flight hardware (typically when more than one item of the same hardware is needed) or as a flight spare. This approach may be dictated by program costs and schedule constraint. A detailed assessment shall be established by the design and quality engineers to determine the necessary refurbishment to make this hardware flight worthy (e.g. replacement of items overstressed or potentially overstressed by qualification testing). After refurbishment, the hardware should be subjected to a partial or complete acceptance test, depending on the extent of refurbishment and disintegration.

4.8.4 Retest during and after long-term storage

Tests performed during and after long-term storage depend on the failure modes likely to occur during storage. At minimum, these tests are necessary to validate moving mechanical assemblies, check preloads, ensure lubrication, and validate interfaces and required functional operations.

4.9 Test documentation

4.9.1 General

The contract between the customer and manufacturer shall call out required test documentation. The following documents are among those most frequently used in the contract to establish detail requirements for the test.

4.9.2 Test plans

Test plans shall provide a general description of each planned test and its conditions. Test plans shall be based on a function-by-function mission analysis and all specified testing requirements. Test objectives shall be planned to verify compliance with the design and specified requirements of the items involved, including interfaces. Test plans shall incorporate or provide references for the following:

a) a brief background of applicable project and descriptions of the test items;

b) an overall test philosophy, testing approach, and test objective for each item, including any special tailoring or interpretation of design and testing requirements.

4.9.3 Test specifications

Test specifications are documents that define test requirements and associated conditions to be implemented to properly demonstrate an item's performance. For some tests (e.g. sinusoidal vibration), test requirements shall be based on test predictions. These documents shall be prepared for each major test activity described in the test plan activity sheets, with the objective to detail test requirements.

4.9.4 Test procedures

Tests shall be conducted using documented test procedures prepared for performing all required tests in accordance with test objectives in approved test plans and specifications. Test objectives, testing criteria, and pass-fail criteria shall be stated clearly in the test procedures. Test procedures shall cover all operations in enough detail to eliminate doubt as to execution of any step. Test objectives and criteria shall be stated clearly to relate to design or operations specifications. Where appropriate, minimum requirements for valid data and pass-fail criteria shall be provided at the procedure step level based on analysis using an appropriate mathematical model. Traceability shall be provided from the specifications or requirements to the test procedures. Where practicable, the individual procedure step that satisfies the requirement shall be identified. The test procedure for each item shall include, at minimum, descriptions of the following:

a) identification of test items;

b) criteria, objectives, assumptions, and constraints;

c) test set-up;

d) initialization parameters;

e) input data;

f) test instrumentation;

g) expected intermediate test results;

h) output data format;

i) expected output data (by supporting analysis and predictions);

j) minimum requirements for valid data to consider the test successful;

k) pass-fail criteria for evaluating results;

l) safety considerations and hazardous conditions;

m) procedural steps required for successful test and verification signature;

n) personnel involved and relevant responsibility.

4.9.5 Test data

Pertinent test data shall be maintained in a quantitative form to permit evaluation of performance under the various specified test conditions; pass or fail statements alone may be insufficient. The test data shall also be compared across major test sequences for trends or evidence of anomalous behavior. To the extent practicable, all relevant test measurements and environmental conditions imposed on the units shall be recorded on computer-compatible electronic media, such as disks, magnetic tape, or other suitable means to facilitate automated accumulation and sorting of data for critical test parameters. These records are intended to be an accumulation of trend data and critical test parameters that shall be examined for out-of-tolerance values and characteristic signatures during transient and mode switching.

4.9.6 Test reports

A summary of the test results shall be documented in test reports. Test reports shall detail the degree of success in meeting the test objectives of the approved test plans and specifications, and shall document test results, deficiencies, problems encountered, and problem resolutions. The test reports shall be provided to the customer and the launch vehicle side to prove compliance with all requirements.

4.9.7 Test log

Formal test conduct shall be documented in a test log. The test log sh all identify personnel involved and be time-tagged to permit reconstruction of test events such as start time, stop time, anomalies, and any periods of interruption.

4.10 Tests facilities and other requirements

The spacecraft, subsystem, and unit tests shall be performed using facilities that simulate the environmental exposure within the specified test tolerance and measure the required operational performance. All test facilities shall have current and valid calibration; controls to avoid over- or under-testing; proven software operational programs; and controlled temperature, humidity, and cleanliness.

4.10.1 Test condition tolerances

Test condition tolerances and measuring precision shall be determined on the basis of the performance of test facilities, and others will be determined by the design standard. Test levels and duration for the design standard should be consistent with the launch environment determined by the launch service providers according to ISO 14303 requirements.

4.10.2 Instrumentation

The instruments to be used for tests shall be calibrated periodically to remain accurate, and each instrument has an expiration date.

5 Spacecraft's system tests

5.1 Test items and sequence

Test items and their sequence shall be defined in a verification/test plan and established early in the program or campaign. Table 1 shows all possible tests from which the set of qualification tests (QT's), acceptance tests (AT's), and proto-flight tests (PFT's) is selected. A minimum test series shall include all items marked as R.

5.2 Test levels and duration

Test levels and duration shall be determined on the basis of the environments to which the system will be exposed, and others will be determined by the design standard. The launch environment shall be determined by the launch service providers.

6 Subsystem/unit tests

6.1 Test items and sequence

The test items and their sequence shall be defined in a verification plan and established early in the program or campaign. The set of QT's may include some or all tests described in table 2. The set of AT's may include some or all tests described in table 3. The set of PFT's may include some or all tests described in table 4.

6.2 Test levels and duration

Test levels and duration shall be determined on the basis of the environments to which the subsystem/unit will be exposed during the service life of the system. The system supplier shall derive the maximum predicted values (AT levels and duration) for each subsystem/unit test.

7 Test requirements

Test requirements specified in this section shall apply to all levels of test articles, including spacecraft, subsystems, and units, as appropriate. Test specifications will be different in imposed levels and duration among models (qualification, flight, and proto-flight). Since such quantitative requirements are not specified in the subsection identified by test levels and duration, requirements for each model shall be specified by test specifications accepted by procurement and launch vehicle authorities, as appropriate.

7.1 Functional test

7.1.1 Purpose of test

The functional test verifies that the electrical and mechanical performance of the test article meet specification requirements.

7.1.2 Test facilities and set-up as basic requirements

Electrical tests shall include application of expected voltages, impedance, frequencies, pulses, and wave forms at the electrical interface of the test article, including all redundant circuits.

Mechanical tests shall include application of torques, loads, and motion of mechanisms as appropriate. These parameters shall be varied throughout their specification range and the sequence of operation expected in flight. Test results shall be used to verify the test article performance with respect to specifications.

Table 1 — Spacecraft QT, AT, and PFT items and sequence

Test	Reference paragraph	Suggested sequence [a]	Minimum test series [b]		
			QT	AT	PFT
Functional	7.1	1,15	R	R	R
EMC	7.2	2	R	O	R
Magnetic field	7.3	19	O	O	O
Antenna pattern [e]	7.4	-	-	-	-
Optical alignment	7.5	4,10,16	R	R	R
Physical properties	7.6	5	R	R	R
Dynamic balance	7.7	20	O	O	O
Launcher/spacecraft interface	7.8	-	R	R	R
Static load [e]	7.9	-	-	-	-
Acceleration [e]	7.10	-	-	-	-
Modal survey [c]	7.11	6	O	O	O
Sinusoidal vibration	7.12	7	R	R	R
Random vibration [d]	7.13	8	R	R	R
Acoustic [d]	7.14	8	R	R	R
Shock	7.15	9	R	O	R
Thermal balance	7.16	13	R	O	R
Thermal vacuum	7.17	14	R	R	R
Thermal cycle	7.18	12	O	O	O
Pressure	7.19	17	R	R	R
Leakage	7.20	3,11,18	R	R	R
Burn in and wear in [e]	7.21	-	-	-	-
Tracking and control system/spacecraft compatibility	7.22	-	R	R	R

[a] The test sequence suggested may be modified according to the efficiency of the operation, schedule of test facilities, and effects to detect malfunctions. However, the following principles may not be changed:

1) Functional tests shall be conducted at the beginning and end of each environmental test, at minimum.

2) The leakage test and alignment check shall be conducted at the beginning and end of the environmental tests, at minimum.

[b] R : recommended, O : optional. - : not required

[c] Some cases can be replaced by a combination of analysis and/or modal survey.

[d] Either vibration or acoustic test is recommended, whichever is more appropriate, with the other discretionary.

[e] These tests are mainly applied to subsystem and unit level.

Table 2 — Subsystem/unit QT items and sequence

Test	Reference paragraph	Suggested sequence[a]	Minimum test series[b]											
			Electrical and electronic	Antenna	MMA	Solar array	Battery	Valve	Propulsion	Pressure vessel	Thruster	Thermal	Optical	Structural
Functional	7.1	4,13,20	R	R[d]	R	R	R	R	R	R	R	R	R	-
EMC	7.2	21	R	O	O	-	-	-	-	-	-	-	-	-
Magnetic field	7.3	22	O	-	O	-	O	R	O	O	O	-	O	-
Antenna pattern	7.4	-	-	R[d]	-	-	-	-	-	-	-	-	-	-
Optical alignment	7.5	5,12,18	-	O	-	-	-	-	-	-	O	-	O	O
Physical property	7.6	2,24	R	R	R	R	R	R	R	R	R	R	R	R
Dynamic balance	7.7	-	-	-	-	-	-	-	-	-	-	-	-	-
Launcher/spacecraft interface	7.8	-	-	-	-	-	-	-	-	-	-	-	-	-
Static load	7.9	1	O	O	O	O	O	O	O	O	O	-	O	R
Acceleration	7.10	3	O	O	O	O	O	-	-	O	-	-	O	-
Modal survey	7.11	7	O	R	O	R	O	-	O	O	O	O	O	R
Sinusoidal vibration	7.12	8	O	O	R	O	R	O	O	R	R	O	O	R
Random vibration	7.13	9	R	R[c]	R	R[c]	R	R	R	R	R	R	R[c]	R[c]
Acoustic	7.14	9	O	R[c]	-	R[c]	-	-	-	-	-	R	R[c]	R[c]
Shock	7.15	10	R	O	O	O	O	O	O	-	O	O	O	R
Thermal balance	7.16	15	O	O	O	O	O	-	O	-	-	O	O	-
Thermal vacuum	7.17	16	R	R	R	R	R	R	R	O	R	R	R	-
Thermal cycle	7.18	14	O	O	O	O	O	O	O	O	O	O	O	O
Pressure	7.19	17	-	-	O	-	R	R	R	R	R	-	-	-
Leakage	7.20	6,11,19	O	-	O	-	R	R	R	R	O	R	-	-
Burn in and wear in	7.21	23	-	-	O	-	-	-	-	-	-	-	-	-

[a] The test sequence suggested may be modified according to the efficiency of the operation, schedule of test facilities, and effects to detect malfunctions. However, the following principles may not be changed:

1) Functional tests shall be conducted at the beginning and end of each environmental test, at minimum.

2) The leakage test and alignment check shall be conducted at the beginning and end of the environmental tests, at minimum.

[b] R : recommended, O : optional, - : not required

[c] Either random vibration or acoustic test is recommended, whichever is more appropriate, with the other discretionary.

[d] Usually, antenna pattern test is performed as part of functional test.

Table 3 — Subsystem/units AT items and sequence

Test	Reference paragraph	Suggested sequence[a]	Minimum test series[b]											
			Electrical and electronic	Antenna	MMA	Solar array	Battery	Valve	Propulsion	Pressure vessel	Thruster	Thermal	Optical	Structural
Functional	7.1	2,14	R	R[d]	R	R	R	R	R	R	R	R	R	-
EMC	7.2	15	O	-	-	-	-	-	-	-	-	-	-	-
Magnetic field	7.3	-	-	-	-	-	-	-	-	-	-	-	-	-
Antenna pattern	7.4	-	-	R[d]	-	-	-	-	-	-	-	-	-	-
Optical alignment	7.5	3,12	-	O	-	-	-	-	-	-	-	-	O	-
Physical property	7.6	1,17	R	R	R	R	R	R	R	R	R	R	R	R
Dynamic balance	7.7	-	-	-	-	-	-	-	-	-	-	-	-	-
Launcher/spacecraft interface	7.8	-	-	-	-	-	-	-	-	-	-	-	-	-
Static load	7.9	-	-	-	-	-	-	-	-	-	-	-	-	-
Acceleration	7.10	-	-	-	-	-	-	-	-	-	-	-	-	-
Modal survey	7.11	5	O	O	O	O	O	-	O	O	-	-	O	O
Sinusoidal vibration	7.12	6	O	O	O	O	-	-	O	O	-	-	O	R
Random vibration	7.13	7	R	R[c]	R	R[c]	R	R	R	R	R	R[c]3	R	R[c]3
Acoustic	7.14	7	O	R[c]	-	R[c]	-	-	-	-	-	R[c]3	O	R[c]3
Shock	7.15	8	O	-	-	-	-	-	-	-	-	-	-	-
Thermal balance	7.16	-	-	-	-	-	-	-	-	-	-	-	-	-
Thermal vacuum	7.17	10	R	O	R	O	R	R	O	O	R	R	R	-
Thermal cycle	7.18	9	O	O	O	O	O	O	O	-	-	-	-	-
Pressure	7.19	11	-	-	O	-	R	R	R	R	O	-	-	-
Leakage	7.20	4,13	O	-	O	-	R	R	R	R	O	R	-	-
Burn in and wear in	7.21	16	R	-	O	-	-	R	-	-	R	-	-	-

[a]The test sequence suggested may be modified according to the efficiency of the operation, schedule of test facilities, and effects to detect malfunctions. However, the following principles may not be changed:

1) Functional tests shall be conducted at the beginning and end of each environmental test, at minimum.

2) The leakage test and alignment check shall be conducted at the beginning and end of the environmental tests, at minimum.

[b]R : recommended, O : optional, - : not required

[c]Either random vibration or acoustic test is recommended, whichever is more appropriate, with the other discretionary.

[d]Usually, antenna pattern test is performed as part of functional test.

Table 4 — Subsystem/units PFT items and sequence

Test	Reference paragraph	Suggested sequence[a]	Minimum test series[b]											
			Electrical and electronic	Antenna	MMA	Solar array	Battery	Valve	Propulsion	Pressure vessel	Thruster	Thermal	Optical	Structural
Functional	7.1	4,13,20	R	R[d]	R	R	R	R	R	R	R	R	R	-
EMC	7.2	21	R	O	O	-	-	-	-	-	-	-	-	-
Magnetic field	7.3	22	O	-	O	-	O	O	O	O	O	-	O	-
Antenna pattern	7.4	-	-	R[d]	-	-	-	-	-	-	-	-	-	-
Optical alignment	7.5	5,12,18	-	O	-	-	-	-	-	-	O	-	O	O
Physical property	7.6	2,24	R	R	-	R	R	R	R	R	R	R	R	R
Dynamic balance	7.7	-	-	-	-	-	-	-	-	-	-	-	-	-
Launcher/spacecraft interface	7.8	-	-	-	-	-	-	-	-	-	-	-	-	-
Static load	7.9	1	O	O	O	O	O	O	O	O	O	-	O	O
Acceleration	7.10	3	O	O	O	O	O	-	-	O	-	-	O	-
Modal survey	7.11	7	O	R	O	R	O	-	O	O	O	O	O	R
Sinusoidal vibration	7.12	8	O	O	R	O	R	O	O	R	R	O	O	R
Random vibration	7.13	9	R	R[c]	R	R[c]	R	R	R	R	R	R	R[c]	R[c]
Acoustic	7.14	9	O	R[c]	-	R[c]	-	-	-	-	-	R	R[c]	R[c]
Shock	7.15	10	O	O	O	O	O	O	O	-	O	O	O	R
Thermal balance	7.16	15	O	O	O	O	O	-	O	-	-	O	O	-
Thermal vacuum	7.17	16	R	R	R	R	R	O	O	O	R	R	R	-
Thermal cycle	7.18	14	O	O	O	O	O	O	O	-	-	-	-	-
Pressure	7.19	17	-	-	O	-	R	R	R	R	R	-	-	-
Leakage	7.20	6,11,19	O	-	O	-	R	R	R	R	O	R	-	-
Burn in and wear in	7.21	23	R	-	O	-	-	R	-	-	R	-	-	-

[a]The test sequence suggested may be modified according to the efficiency of the operation, schedule of test facilities, and effects to detect malfunctions. However, the following principles may not be changed:

1) Functional tests shall be conducted at the beginning and end of each environmental test, at minimum.

2) The leakage test and alignment check shall be conducted at the beginning and end of the environmental tests, at minimum.

[b]R : recommended, O : optional, - : not required

[c]Either random vibration or acoustic test is recommended, whichever is more appropriate, with the other discretionary.

[d]Usually, antenna pattern test is performed as part of functional test.

Functional test shall also include electrical continuity, stability, response time, or other special functional tests related to a particular configuration.

7.1.3 Test article configuration

Functional tests shall also be performed while the environment is being imposed, if the test article is expected to be fully operational in that environment (except for solar panels, antennas, propellant, etc. during thermal vacuum test). Simulated thruster valves and batteries will also be adopted to verify overall compatibility.

7.1.4 Monitoring during test

A database of critical parameters shall be established for trend analysis. Any unusual or unexpected trends shall be evaluated to determine the existence of drift toward out-of-limit value or incipient failure.

7.1.5 Test levels and duration

There are no mandatory requirements.

7.1.6 Test condition and guidelines

The hardware configuration for system and subsystem/unit functional testing shall consist of all flight hardware and applicable flight software. Through the test article environmental tests, sequential functional tests shall confirm that no degradation has occurred. Satisfactory electrical performance shall be demonstrated in all applicable operational modes before, during, and after specified environmental exposures. During the test, the spacecraft electrical and mechanical subsystems/units shall be in various operational modes appropriate for launch and orbital configurations. At that time, all subsystems/units shall be powered, if possible. Test requirements for functional tests shall be defined not only for those tests performed before and after environmental tests, but also for functional and performance verification of the items under test.

7.1.7 Tailoring guide

Complete functional tests shall be performed at the beginning and end of the test sequence. Partial functional test shall be conducted before and after each environmental exposure.

7.2 Electromagnetic compatibility (EMC) test

7.2.1 Purpose of test

The EMC test demonstrates the test article compatibility with the induced environment and ensures that adequate margins exist in a simulated electromagnetic environment during the service life and in all possible operational modes, as applicable.

7.2.2 Test facilities and set-up as basic requirements

Test facilities and set-up shall be prepared for far-field environment and radio frequency (RF) environment, which simulate the actual space environment. External RF signals shall be shielded. Spurious RF reflected signals shall be minimized. Discrimination between spurious and intentional emissions shall be performed for EMC test data evaluation. Telemetry/telecommand and RF communication signals shall be tested using airlink configuration.

7.2.3 Test article configuration

Two configurations shall be tested – the on-orbit configuration, and the pre-launch through plus-count and separation configuration. Electroexplosive devices (EED's) used to initiate spacecraft functions (such as appendages deployment and separation) shall be replaced by inert EED's except for bridgewires.

7.2.4 Monitoring during test

During EMC tests, power ripple and peak transients shall be measured. Selected critical parameters shall be monitored.

7.2.5 Test levels and duration

The test program (emission and susceptibility) shall comply with International Standard 14302 requirements. Supplementary requirements as necessary to achieve EMC compliance are provided by the product provider's specifications and interface documents (launch manual, etc.).

7.2.6 Test condition and guidelines

The operation of spacecraft and selection of instrumentation shall be suitable for determining the margin against malfunctions and unacceptable or undesired responses resulting from electromagnetic incompatibilities. The test shall demonstrate satisfactory electrical and electronic equipment operation in conjunction with the expected electromagnetic radiation and conduction from other subsystems or units, such as from other spacecraft elements and the launcher. The electromagnetic radiation and conduction from the spacecraft shall not disturb the launcher. An electrostatic arc discharge susceptibility test shall be conducted if the spacecraft has the possibility of disturbance that may arise from electrostatic discharge on orbit. Inert EED's shall be installed and monitored during all tests.

EMC between system and subsystem shall be demonstrated functionally with required margins.

7.2.7 Tailoring guide

EMC test will be performed only once in the test flow for each test article.

7.3 Magnetic field test

7.3.1 Purpose of test

The magnetic field test determines the permanent and induced magnetic moments of the test article and demonstrates compliance with magnetic cleanliness requirements.

7.3.2 Test facilities and set-up as basic requirements

There are no mandatory requirements.

7.3.3 Test article configuration

The on-orbit configuration shall be represented as much as possible.

7.3.4 Monitoring during test

There are no mandatory requirements.

7.3.5 Test levels and duration

There are no mandatory requirements.

7.3.6 Test condition and guidelines

When a precise estimation of the system-level magnetic moments is required (such as a spacecraft that carries magnetometers or in which magnetic torque is one major disturbance factor), a magnetic field test shall be conducted on the spacecraft. If necessary in order to estimate or control spacecraft-level magnetic moments, a subsystem- or unit-level magnetic field test shall be performed.

7.3.7 Tailoring guide

If there are no stringent magnetic cleanliness requirements related to the test article, this test may be replaced by analysis.

7.4 Antenna pattern test

7.4.1 Purpose of test

The antenna pattern test verifies the characteristics of the antenna for spacecraft configuration during launch and orbit operational phases.

7.4.2 Test facilities and set-up as basic requirements

The spacecraft shall be subjected to a comprehensive test program at an appropriate antenna test facility to accurately determine the radiation pattern and phase (if appropriate) of each spacecraft antenna.

7.4.3 Test article configuration

The test shall be conducted for each spacecraft configuration in which the antennas will be operated. The test article configuration shall be representative of external spacecraft shape, including deployable appendages.

7.4.4 Monitoring during test

There are no mandatory requirements.

7.4.5 Test levels and duration

There are no mandatory requirements.

7.4.6 Test condition and guidelines

There are no mandatory requirements.

7.4.7 Tailoring guide

If it is not possible to perform the antenna pattern test for spacecraft configuration, mock-ups, or scale models simulating the spacecraft may be used.

7.5 Optical alignment measurement

7.5.1 Purpose of test

The optical alignment measurement determines if the optical alignments of the test article are within specified tolerances for the spacecraft.

7.5.2 Test facilities and set-up as basic requirements

Test facilities and set-up shall be prepared so the necessary angle may be measured within specified tolerances. Test articles shall be subjected to measurement of the mounted locations and the angles subtended between the spacecraft axes and optical sensors, antennas, nozzles, and thrusters.

7.5.3 Test article configuration

The test article shall be equipped with all necessary optical gauging and references so appropriate angles may be measured.

7.5.4 Monitoring during test

There are no mandatory requirements.

7.5.5 Test levels and duration

There are no mandatory requirements.

7.5.6 Test condition and guidelines

In addition to initial baseline alignment measurements, the test shall be performed before and after environment tests (such as vibration and thermal environment) and after major transportation that may affect alignment of test articles.

7.5.7 Tailoring guide

Alignment measurements to be performed before and after thermal environment tests may be omitted if the alignment predicted values demonstrate large margins with respect to specification requirements.

7.6 Physical property measurement

7.6.1 Purpose of test

The physical property measurement determines the physical characteristics of the test article (i.e. dimensions, mass, center of gravity, and moment of inertia). Dynamic balance tests are described in section 7.7.

7.6.2 Test facilities and set-up as basic requirements

The test article shall be installed in facilities capable of measuring physical characteristics.

7.6.3 Test article configuration

The test article shall be in launch configuration. Any flight items that cannot be installed and any nonflight items (such as testing fixtures) that cannot be removed shall be compensated for by analysis.

7.6.4 Monitoring during test

There are no mandatory requirements.

7.6.5 Test levels and duration

There are no mandatory requirements.

7.6.6 Test condition and guidelines

The test conditions and guidelines shall measure parameters of dimensions, mass, center of gravity, and moment of inertia that are required in predicting vehicle performance during boost and spacecraft orientation during injection and orbit. If measurements are performed with an empty tank, a correlation with the analytical model (tank full) shall be done.

7.6.7 Tailoring guide

If the analysis of physical properties has large margins, this test may be omitted, except for mass measurement.

7.7 Dynamic balance

7.7.1 Purpose of test

The dynamic balance test compensates unbalances such as center of gravity offset and product of inertia around the defined coordinate axes (normally the geometric spin axis). This test shall be performed for sensors, spacecraft, or upper stages that have balance requirements that cannot be verified by analysis.

7.7.2 Test facilities and set-up as basic requirements

The test article shall be installed on the appropriate dynamic balance machine.

7.7.3 Test article configuration

The test article shall be as closely representative as possible of the configuration of critical balance for the mission. If dynamic balance testing is done with empty tanks, a correlation with the analytical model (tank full) shall be done. Any flight items that cannot be installed and any nonflight items (such as testing fixtures) that cannot be removed shall be compensated for by analysis.

7.7.4 Monitoring during test

There are no mandatory requirements.

7.7.5 Test levels and duration

Test accuracy and duration depend on mission profile and spin rates.

7.7.6 Test condition and guidelines

The initial balance if required shall verify the feasibility of attaining the stipulated final balance and evaluate the method of attaching the balance mass and its effect on the operation of the test article during environmental tests. Final balance is performed to properly adjust for all changes to mass distribution made during the test program, such as unit replacement or redesign. It is recommended that changes to the system that may affect weight distribution be minimized after completion of the final balance test.

7.7.7 Tailoring guide

When the required accuracy can be met, small mass items that may not be assembled during test shall be accounted for by analysis.

7.8 Launcher/spacecraft interface test

7.8.1 Purpose of test

The launcher/spacecraft interface test shall be performed to verify the interfaces between launcher and spacecraft, which are defined in ISO14303.

7.8.2 Test facilities and set-up as basic requirements

The test article shall be tested in facilities capable of handling the spacecraft.

7.8.3 Test article configuration

The physical/electrical interface of test article shall be in launch configuration.

7.8.4 Monitoring during test

There are no mandatory requirements.

7.8.5 Test levels and duration

Test levels and duration are derived from the respective launch vehicle user manual and spacecraft design standard.

7.8.6 Test condition and guidelines

A team composed of both the launcher and spacecraft side shall perform this test. The location and time of each test shall be determined by launcher and spacecraft coordination. The verification of electrical interface shall be performed before launch site test except for clean interface. The measurement of interface dimensions, or fit checks, with master gauges shall be performed to verify the mechanical interface. The optional umbilical connector pull-out test checks separation.

7.8.7 Tailoring guide

There are no mandatory requirements.

7.9 Static load test

7.9.1 Purpose of test

The static load test demonstrates the ability of the primary structure of a spacecraft or a large structural subsystem (for example, antenna, solar panel, observation instrument) to sustain the quasi-static loads induced by the launch vehicle, apogee boost motor, and spin motion.

7.9.2 Test facilities and set-up as basic requirements

The support and load fixture shall duplicate the boundary conditions and the load levels of the flight environment. Primary structure shall be mounted on a test fixture that has the same structural characteristics as the spacecraft adapter. Large structural subsystem shall be mounted on a support fixture that duplicates spacecraft interface.

7.9.3 Test article configuration

The model to which the static load test is applied shall have the same configuration, material, and production process as those of the flight model.

7.9.4 Monitoring during test

Strain and deformation shall be recorded during test and after removal of the test load; and, if required, the loads shall be increased until structural failure occurs in order to evaluate the design margin.

7.9.5 Test levels and duration

The loads shall be increased step by step until the stipulated test load is applied. At each load level, strain and deformation shall be recorded. Considering the critical flight temperature and load combinations, load levels shall be determined so the expected worst-case stress may be applied. Dwell time at each load level shall be the minimum time required to complete recording of stress, strain, deformation, and temperature.

7.9.6 Test condition and guidelines

The test conditions shall encompass the extreme predicted combined effects of acceleration, vibration, pressure, and temperature. These effects may be simulated in the test conditions as long as the combined effects are covered by the design margins.

7.9.7 Tailoring guide

A large centrifuge acceleration test facility or shaker excitation may be used in place of the stationary test method.

7.10 Acceleration test

7.10.1 Purpose of test

The acceleration test is intended for a unit sensitive to static acceleration. It shall be performed to determine the ability of a unit to maintain structural integrity and operate correctly when it is subjected to constant acceleration generated during the launch.

7.10.2 Test facilities and set-up as basic requirements

The test article shall be attached, as it is during the launch, to a test fixture and subjected to acceleration in the appropriate directions.

7.10.3 Test article configuration

The test article shall be mounted to a test fixture through its normal mounting points. If necessary, the test article shall be protected by a shroud. The test article shall be tested in each of three mutually perpendicular axes, if other conditions are not determined by the test program.

7.10.4 Monitoring during test

Before and after each acceleration test, electrical performance and mechanical functioning tests of the test article shall be performed.

7.10.5 Test levels and duration

Test levels and duration are specified in the respective launch vehicle user manual.

7.10.6 Test condition and guidelines

The specified acceleration shall be applied to the center of gravity of the test item. If a centrifuge is used, the arm (measured to the geometric center of the test item) shall be longer than the dimension of the test item measured along the arm. The acceleration gradient across the test item shall not result in acceleration that falls below the qualification level on any critical member of the test item. Inertial units (such as gyroscopes and platforms) may require counter-rotating fixtures on the centrifuge arm.

7.10.7 Tailoring guide

There are no mandatory requirements.

7.11 Modal survey

7.11.1 Purpose of test

The modal survey test determines experimentally the natural frequency, mode shapes, and damping factors of the test article throughout the dynamically relevant range. Results of a modal survey determine whether or not any natural frequencies fall into an undesirable range and/or adjust the natural frequencies and modes determined analytically with the help of a finite element mathematical model of the structural system. Once the latter is in good agreement with the physical system, it may be used to predict structural responses.

7.11.2 Test facilities and set-up as basic requirements

There are three typical methods: base excitation, single-point excitation, and multiple-point excitation. In each case, the boundary condition shall be carefully considered in order to not affect its natural frequencies and mode shapes.

7.11.3 Test article configuration

The test article shall be the flight or qualification model to the maximum extent practicable. If simulators are used as subsystems/units, they shall be representative of the omitted subsystems/units in mass, and the center of gravity will be designed to not stiffen the test article.

7.11.4 Monitoring during test

Instrumentation shall be adequate to verify the analytical model for main structural modes in the range of interest.

7.11.5 Test levels and duration

There are no mandatory requirements.

7.11.6 Test condition and guidelines

In general, support of the test article during test shall duplicate the boundary conditions expected during launch. When that is not feasible, other boundary conditions will be employed and the frequency of the test will be adjusted accordingly. Interface flexibility shall be considered when other-than-normal boundary conditions are used. Any test method capable of meeting the test objectives with necessary accuracy may be used to perform the modal survey. The input-forcing function may be transient, fixed frequency, sweep sine wave, or random nature.

7.11.7 Tailoring guide

After an acceptable modal survey as defined by program requirement has been conducted on a representative structural model, a modal survey of the flight and the proto-flight models may be unnecessary. A representative structural model is defined as one that duplicates the structure in materials, configuration, fabrication, and assembly methods. It is also one that satisfactorily simulates other items mounted on the structure in location, method of attachment, and physical properties.

7.12 Sinusoidal vibration test

7.12.1 Purpose of test

The sinusoidal vibration test demonstrates that the test article can withstand low-frequency excitations of the launch vehicle or other self-induced sinusoidal vibration environments.

7.12.2 Test facilities and set-up as basic requirements

The test article shall be placed in a vibration test facility capable of generating vibration sufficient for the test requirement. The test article shall be mounted to a fixture at the normal mounting points. Vibrations shall be applied in three mutually orthogonal directions, one being parallel to the thrust axis.

7.12.3 Test article configuration

The test article shall be in launch configuration. Propellant tanks may be empty during spacecraft testing, provided the filled-tank configuration has been test-validated. Antennas and other devices that extend or change position after orbital injection shall be in launch configuration during the test article response.

7.12.4 Monitoring during test

During system vibration test, the test article shall be operated in a duty cycle typical of that to be employed at the launch phase and monitored for malfunctions in telemetry and all other systems that operate during boost. Subsystem and unit tests shall be performed with the article powered. Exact requirements for such monitoring shall be specified in the test plan for a particular test article.

7.12.5 Test levels and duration

Test levels and duration are derived from the respective launch vehicle user manual and spacecraft design standard. The final requirements shall be specified in the test specification reflecting the strategy defined in the verification plan considering other factors.

7.12.6 Test condition and guidelines

The required conditions of the sinusoidal vibration test are as follows:

a) accelerometer and shaker control

For sinusoidal vibration test, at least one control accelerometer shall be attached rigidly on the test fixture near the fixture-spacecraft adapter interface and aligned with the axis of applied vibration. Sinusoidal excitations shall be applied at the base of the mounting adapter.

b) requirements for pressurized vessels

Normally, sealed units shall be pressurized to their prelaunch pressure. In cases of significant changes in strength, stiffness, or applied loads resulting from variations in internal or external pressure during launch phase, a special vibration test shall be performed to evaluate those effects.

If the filling material is toxic or explosive, a fluid or gas having equivalent physical properties of no toxicity and no adverse effect on the test article shall be used.

7.12.7 Tailoring guide

Notching shall be used to prevent the overstress and shall be based on the coupled load analysis. These cases concern items having fundamental frequencies below 100Hz. Notching procedures may be acceptable during vibration testing by agreement with contracting authority.

7.13 Random vibration test

7.13.1 Purpose of test

The random vibration test demonstrates that the test article can withstand the random vibration environment imposed during its service life.

7.13.2 Test facilities and set-up as basic requirements

The test articles shall be placed in a vibration test facility capable of generating vibrations that are sufficient to provide test requirement environment. The test article shall be mounted to a fixture at the normal mounting points. Random excitations shall be applied in three mutually orthogonal directions, one being parallel to the thrust axis.

7.13.3 Test article configuration

The test article shall be in launch configuration. Propellant tanks may be empty during spacecraft testing, provided that the filled-tank configuration has been test-validated. Antennas and other devices that extend or change position after orbital injection shall be in launch configuration during the test article response.

7.13.4 Monitoring during test

During system vibration test, the test article shall be operated in a duty cycle typical of that to be employed at the launch phase and monitored for malfunctions in telemetry and all other systems that operate during boost. Subsystem and unit tests shall be performed with the article powered. Exact requirements for such monitoring shall be specified in the test plan for a particular test article.

7.13.5 Test levels and duration

Test levels and duration are specified in the respective launch vehicle user manual and spacecraft design standard; however, the final requirements shall be specified in the test specification reflecting the strategy defined in the verification plan.

7.13.6 Test condition and guidelines

The required conditions of the random vibration test are as follows:

a) accelerometer and shaker control

For random vibration test, at least one control accelerometer shall be attached rigidly on the test fixture near the fixture-spacecraft adapter interface and aligned with the axis of applied vibration. Random excitations shall be applied at the base of the mounting adapter.

b) requirements for pressurized vessels

Normally, sealed units shall be pressurized to their prelaunch pressure. In cases of significant changes in strength, stiffness, or applied loads resulting from variations in internal or external pressure during launch phase, a special vibration test shall be performed to evaluate those effects.

If the filling material is toxic or explosive, a fluid or gas having equivalent physical properties of no toxicity and no adverse effect on the test article shall be used.

7.13.7 Tailoring guide

Random vibration tests may be waived if acoustic tests are to be performed, provided that the acoustic input envelops the structureborne input at the article mounting location. The selection of either of these tests is specified in the test specification of a particular test article.

7.14 Acoustic test

7.14.1 Purpose of test

The acoustic test demonstrates the ability of the test article to endure acoustic levels imposed by the launch vehicle and validates unit random test levels.

7.14.2 Test facilities and set-up as basic requirements

The test article shall be installed in an acoustic test facility capable of generating sound fields at or above the levels imposed by the launch vehicle.

7.14.3 Test article configuration

The test article shall be in launch configuration. Propellant tanks may be empty during spacecraft testing, provided that the filled-tank configuration has been test-validated. Significant fluid and pressure conditions shall be replicated to the extent practicable. Appropriate dynamic instrumentation shall be installed to validate test article responses.

7.14.4 Monitoring during test

During the tests, the test article shall be operated in a duty cycle typical of that to be employed at launch and during boost and monitored to verify that interface and interoperability requirements are met.

7.14.5 Test levels and duration

Test levels and duration are specified in the respective launch vehicle user manual and design standard.

7.14.6 Test condition and guidelines

Normally, sealed units shall be pressurized to their prelaunch pressure. If the filling material is toxic or explosive, a fluid or gas having equivalent physical properties of no toxicity and no adverse effect on the test article shall be used. In the test, the chamber sound pressure level and test article structure response acceleration shall be measured.

7.14.7 Tailoring guide

The random vibration test may be conducted instead of an acoustic test for small, compact test articles that can be exited more effectively via interface vibration than by an acoustic field.

If strength, stiffness, and applied loads resulting from changes of internal and external pressure are not changed significantly or can be estimated with enough accuracy, the pressurized units may not need to be pressurized.

7.15 Shock test

7.15.1 Purpose of test

The shock test demonstrates the capability of the test article to meet requirements during and after exposure to the shock environment during its service life.

7.15.2 Test facilities and set-up as basic requirements

The test article in a flight configuration shall be installed in a shock test facility capable of generating shock transient time histories and shock response spectra simulating the environment. Where feasible, flight structure and flight duplicate shock-producing hardware may be employed.

7.15.3 Test article configuration

The test article shall be supported and configured to allow flight-like dynamic response of the article with respect to amplitude, frequency content, and paths of transmission.

7.15.4 Monitoring during test

During the tests, the test article shall be operated and monitored for malfunctions.

7.15.5 Test levels and duration

Test levels and duration are specified in the respective launch vehicle user manual and spacecraft design standard.

7.15.6 Test condition and guidelines

Test conditions shall be determined by the type of shock and shock phase.

7.15.7 Tailoring guide

If the specified shock spectrum is enveloped by the random vibration spectrum and propagation path and damping characteristics are well known, the shock test may be eliminated.

7.16 Thermal balance test

7.16.1 Purpose of test

The thermal balance test shall provide the data necessary to verify the analytical thermal model and demonstrate the ability of the spacecraft thermal control subsystem to maintain the specified operational temperature limits of the units throughout the entire spacecraft.

7.16.2 Test facilities and set-up as basic requirements

The thermal balance test shall be conducted on the spacecraft. When the subsystem/unit has its own thermal control capability independent of a spacecraft's thermal control subsystem, a subsystem/unit-level thermal balance test shall also be performed.

7.16.3 Test article configuration

The test article shall be placed in a thermal vacuum chamber capable of simulating the thermal flow expected during the mission. The thermal state of the test article may be obtained by simulating the incident radiation and/or the heat absorbed. Selection of the method depends on the test article configuration and geometry, relation of internally produced heat to the external heat influx, and thermal characteristics of the external surface. Both onboard sensors and monitoring thermal sensors for the test shall be installed according to the thermal analysis for monitoring and acquiring thermal data.

7.16.4 Monitoring during test

The test article shall be operated and monitored throughout the test. Functional tests shall be conducted before, during, and after the test.

7.16.5 Test levels and duration

The approach to the thermal balance test shall be based on simulating the thermal conditions predicted to be the most critical for the thermal control subsystem. The test profile depends on the mission, spacecraft design, spacecraft operating modes, and times required to reach stabilization. At minimum, two test conditions shall be imposed: the worst hot case and the worst cold case. The exposure shall be long enough for the test article to reach stabilization so temperature distributions in the steady-state conditions may be verified.

7.16.6 Test condition and guidelines

Success criteria depend not only on survival and operation of each item within the specified temperature limits but also on correlation of the test data with theoretical thermal models. Lack of correlation with the theoretical models may indicate a deficiency in either the test mode, test set-up, test article hardware, or mistakes in mathematical model itself. The correlated thermal mathematical model shall be used to make the final temperature predictions for the various mission phases.

7.16.7 Tailoring guide

If there is a sufficient margin between the worst predicted temperature and the allowable design limit and the results of analysis and test for thermal model verify the sufficiency of the margin, the thermal balance test may be omitted.

7.17 Thermal vacuum test

7.17.1 Purpose of test

The thermal vacuum test demonstrates the ability of the test item to meet the design requirements under vacuum conditions and temperature extremes that simulate those predicted for flight. The thermal vacuum test detects material, process, and workmanship defects that would respond to vacuum and thermal stress conditions.

7.17.2 Test facilities and set-up as basic requirements

The test article shall be placed in a thermal vacuum chamber and functional test shall be performed to ensure readiness for chamber closure. The chamber may be programmed to achieve the required thermal extreme's sequence. Execution of the sequence shall be coordinated with expected environmental conditions, and a complete cycling of all hardware shall be performed, including the operation and monitoring of redundant units and paths. Strategically placed witness plates or other instrumentation shall be installed in the test chamber to measure the outgassing from spacecraft, subsystems, and units.

7.17.3 Test article configuration

The test article shall be placed in a thermally controlled vacuum chamber having the capability to expose the test article at or beyond the minimum and maximum test temperatures. It may be necessary to achieve temperature limits at certain locations by altering thermal boundary conditions locally or by altering the operational sequence to provide additional heating or cooling. Adjacent equipment may be turned on or off; however, any special conditioning within the test article would generally be avoided. External baffling, shadowing, or heating may be utilized to the extent feasible. Not only onboard thermal sensors but also monitoring thermal sensors for testing shall be installed as indicated by the thermal analysis for monitoring and acquiring thermal data.

7.17.4 Monitoring during test

The test article shall be operated and monitored throughout the test. A functional test shall be conducted before, during, and after the test.

The functional tests performed during thermal vacuum test shall include the following minimum requirements:

a) electrical discharge check during pumping down;

b) operation at minimum cold temperature stress conditions;

c) operation at maximum hot temperature stress conditions;

d) transitions between temperature extremes while operating;

e) hot and cold turn-on capabilities shall be demonstrated at extreme conditions.

7.17.5 Test levels and duration

The test temperature shall be determined on the following conditions:

a) QT: the design temperature and qualification margin;

b) AT: the design temperature.

The soak duration, number of cycles, test profile, and test configuration shall be specified in the test specification based on a number of factors such as the test article design (test operation modes, heat inertia characteristics, etc.). Test facility characteristics (heat capacity, heater configuration, etc.) can also affect configuration.

7.17.6 Test condition and guidelines

Units that operate during ascent shall be operating and monitored for corona and multipacting during chamber pressure reduction. Radio frequency (RF) units shall be operated at the maximum power and design frequency to demonstrate the absence of corona and multipaction.

7.17.7 Tailoring guide

If the units are not sensitive to the vacuum environment, the test may be replaced with thermal cycle test at ambient pressure.

7.18 Thermal cycle test

7.18.1 Purpose of test

The thermal cycle test demonstrates the ability of the test article to meet all functional and performance requirements over a temperature range at ambient pressure. The thermal cycle test, in combination with a reduced-cycle thermal vacuum test, may be selected as an alternate to the thermal vacuum test.

7.18.2 Test facilities and set-up as basic requirements

The test article shall be placed in a thermally controlled chamber. The test facility shall provide functions to conduct a functional test, including test for redundant units, in various operation modes under various thermal environments.

7.18.3 Test article configuration

The test article shall be placed in a thermally controlled chamber having the capability to expose the test article to environments equal to or beyond the minimum and maximum test temperatures. For spacecraft, it may be necessary to achieve temperature limits at certain locations by altering thermal boundary conditions locally or by altering the operational sequence to provide additional heating or cooling.

7.18.4 Monitoring during test

A functional test shall be performed to ensure readiness for the test. The test article shall be operated and monitored during the test, except that the article power may be turned off if necessary to reach stabilization at the cold temperature.

7.18.5 Test levels and duration

Test levels and duration for units are derived from the system analysis that is based on life-cycle mission requirements. Ambient pressure is normally used; however, the thermal cycle test may be conducted at reduced pressure, including vacuum conditions. When unsealed units are being tested, provisions shall be taken to preclude condensation on and within the unit at low temperature.

7.18.6 Test condition and guidelines

Throughout the test, humidity control shall be exercised to maintain the dew point temperature of the test chamber air below the temperature, in order to avoid condensation. One complete thermal cycle is a period beginning at ambient temperature, transitioning to one temperature extreme and stabilizing, then transitioning to the other temperature extreme and stabilizing, and finally returning to ambient temperature. Strategically placed temperature monitors installed on units shall ensure attainment and stabilization of the expected temperature extremes for several units. Auxiliary heating and cooling may be employed for selected temperature-sensitive units (e.g.

batteries). If it is necessary in order to achieve the required rate of temperature change, parts of the spacecraft (such as solar arrays and passive thermal equipment) may be removed for the test. The last thermal cycle shall contain cold and hot soaks during which the test article shall undergo a functional test, including testing of redundant functions.

7.18.7 Tailoring guide

The ambient thermal cycle test may be combined with thermal vacuum test.

7.19 Pressure test

7.19.1 Purpose of test

In a QT, the pressure test demonstrates adequate design and structure integrity of the pressurized structure, vessels, and units such that structural failure or excessive deformation does not occur at the maximum expected operating pressure (MEOP). In an AT, the pressure test detects material and workmanship defects that could result in the failure of the test article.

7.19.2 Test facilities and set-up as basic requirements

The test article shall be placed in a facility that provides the services and safety conditions required to protect personnel during testing and handling of dangerous fluids. Checks for cleanliness, moisture levels, and pH levels of the test article and fluids should also be made, if applicable.

7.19.3 Test article configuration

Where pressurized subsystems are assembled with other than brazed or welded connections, specified torque values for these connections shall be verified prior to the initial leak check.

7.19.4 Monitoring during test

The test article shall be exposed to the internal pressure normally used for propellant loading and the pressure monitored for decay as an indication of leakage. A functional test shall be conducted before, during, and after the test, if necessary. For burst test, the actual pressure shall be measured.

7.19.5 Test levels and duration

The required test levels and duration are as follows:

a) temperature and humidity

The test conditions shall be consistent with the operational temperature and humidity. As an alternative, tests may be conducted at ambient conditions if the test pressure is adjusted to account for temperature and humidity effects on material strength and fracture toughness.

b) proof pressure

The minimum proof pressure for all pressurized items shall be multiplied by the required safety factor. The pressurized subsystem shall be pressurized to a proof pressure and held constant for a short dwell time, sufficient to ensure that the proper pressure was achieved within the allowed test tolerance.

c) pressure cycle

The number of pressure cycles shall be equal to the maximum number of operational cycles multiplied by the required factor.

d) burst pressure

The minimum design burst pressure for pressurized vessels and units shall be at least twice the MEOP. The design burst pressure shall be maintained for the minimum time sufficient to ensure that the proper pressure was achieved.

7.19.6 Test condition and guidelines

Applicable safety standards and operational standards in ISO 14623 shall be applied in conducting all tests.

7.19.7 Tailoring guide

The QT of pressure vessels shall include a demonstration of a leak-before-burst (LBB) failure mode. The LBB pressure test may be omitted if material data are available to be used for an analytical demonstration of the LBB failure mode.

7.20 Leakage test

7.20.1 Purpose of test

The leakage test demonstrates the capability of pressurized items and hermetically sealed units to meet the specified design leakage rate requirements.

7.20.2 Test facilities and set-up as basic requirements

The test article shall be placed in a facility that provides the services and safety conditions required to protect personnel and equipment during testing and handling of dangerous fluids. Checks for cleanliness, moisture levels, and pH levels of the test article should also be made.

7.20.3 Test article configuration

Where pressurized subsystems are assembled with other than brazed or welded connections, the specified torque values for these connections shall be verified prior to the initial qualification leak check.

7.20.4 Monitoring during test

There are no mandatory requirements.

7.20.5 Test levels and duration

The test article would be exposed to internal pressure adequate to monitor decay as an indication of leakage. The leakage test shall be performed with the unit pressurized at the maximum differential operating pressure, as well as at the minimum differential operating pressure, if the seals depend on pressure for proper sealing. The test duration shall be sufficient to detect any significant leakage.

7.20.6 Test condition and guidelines

An acceptable leak rate to meet mission requirements is based upon development tests and appropriate analyses. An acceptable measurement technique is one that accounts for leak rate variations with differential pressure and hot and cold temperatures and has the required threshold, resolution, and accuracy to detect any leakage equal to or greater than the maximum acceptable leak rate. If appropriate, the leak rate test shall be made at qualification hot and cold temperatures with the representative fluid to account for geometry alterations and viscosity changes.

7.20.7 Tailoring guide

A special bag that envelops the entire spacecraft or localized areas or other special techniques may be required to achieve the required accuracy.

7.21 Burn-in and wear-in test

7.21.1 Purpose of test

The burn-in and wear-in test shall detect material and workmanship defects that occur early in the unit life.

7.21.2 Test facilities and set-up as basic requirements

There are no mandatory requirements.

7.21.3 Test article configuration

The test article is flight unit or qualification unit.

7.21.4 Monitoring during test

Perceptive parameters shall be monitored during the burn-in and wear-in test to detect evidence of degradation. Operation shall be under conditions representative of operational cycle, load, speeds, and environments.

7.21.5 Test levels and duration

7.21.5.1 Pressure

Ambient pressure shall normally be used.

7.21.5.2 Temperature

Ambient temperature shall be used for operations if the test objectives can be met. Otherwise, temperatures representative of the operational environment shall be used.

7.21.5.3 Duration

The number of test cycles is based on the engineering specification. A modified thermal cycling test shall be used to accumulate the additional operational hours required for the burn-in test of electrical units.

7.21.6 Test condition and guidelines

For valves, thrusters, and other items for which the number of cycles of operation rather than hours of operation is a better method to ensure detection of infant mortalityfailures, functional cycling shall be conducted at ambient temperature. For thrusters, a cycle is a hot firing that includes a start, steady-state operation, and shutdown. For hot firing of thrusters utilizing hydrazine propellants, action shall be taken to ensure the flight valves are thoroughly cleaned of all traces of hydrazine following the firing.

7.21.7 Tailoring guide

Units that have extremely limited life cycles, such as positive expulsion tanks, are excluded from wear-in test requirements.

7.22 Tracking and control system/spacecraft compatibility test

7.22.1 Purpose of test

The tracking and control system/spacecraft compatibility tests shall verify that spacecraft operation can be controlled and operated by the specified ground network.

7.22.2 Test facilities and set-up as basic requirements

The set-up shall include hard-line and RF airlink for the telemetry/telecommand signal.

7.22.3 Test article configuration

The flight configuration is mandatory except for solar arrays and fueled-propulsion subsystem.

7.22.4 Monitoring during test

Test data shall be compared with previously obtained data to identify trends in performance parameters.

7.22.5 Test levels and duration

There are no mandatory requirements.

7.22.6 Test condition and guidelines

Compatibility tests are unique to an individual spacecraft program and shall comply with the launch operation schedule at the launch site.

7.22.7 Tailoring guide

There are no mandatory requirements.